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YUKON RIVER SONAR ESCAPEMENT ESTIMATE

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by

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ABSTRACT

The Yukon River sonar project has estimated daily upstream passage of chinook salmon *(Oncorhynchus tshawytscha)*, summer and fall chum salmon *(O. keta)*, and coho salmon *(O. kisutch)* since 1986. The project was operational in 1991 from 5 June through 1 September. Fish passage for each species was estimated through a two component process: (1) estimation of total fish passage with single-beam sonar, and (2) estimation of species proportions by test-fishing with gill nets of seven different mesh sizes. A total of 1,875,334 ± 38,200 (s.e.) fish passed upstream through the sonar beams in 1991, 31% along the right bank and 69% along the left bank. Included were an estimated 58,079 ± 7,023 chinook salmon (excluding fish <700 mm long), 1,232,874 ± 36,130 summer-run chum salmon, 240,740 ± 14,646 fall-run chum salmon, and 59,822 ± 4,797 coho salmon. Data from bank-to-bank transects with downward-looking sonar were used to estimate passage of fish beyond the range of the shore-based sonar after 20 July. Transect data indicated that an additional 356,182 ± 62,740 fall-run chum salmon and 10,903 ± 5,747 coho salmon passed beyond the range of the shore-based sonar.

KEY WORDS: salmon, hydroacoustic, Yukon River, escapement, species apportionment, net selectivity

INTRODUCTION

Salmon (*Oncorhynchus* spp.) are harvested for both commercial and subsistence purposes over more than 1,600 km of the Yukon River in Alaska and Canada. Management of the fishery requires in-season knowledge of run strength and escapement levels. Such information is difficult to obtain in the Yukon River due to its large size, multiple channels, and highly turbid water.

Management of the fishery has been based on information obtained from several sources, each having unique strengths and weaknesses. Visual surveys of clear-water spawning tributaries provide stock-specific indices of escapement. These indices, however, are highly dependent on survey timing and spawner stream life, may not be representative of total system escapement levels, and most importantly are not available for in-season management use. Hydroacoustic estimates of salmon escapement in spawning tributaries have similar limitations for in-season management of Yukon drainage fisheries. Gill-net test fishery catches near the river mouth provide in-season indices of run-strength, but use of these data is confounded by gill net selectivity, changes in net site characteristics, and varying fish migration routes through the multichannel river mouth.

Hydroacoustic estimates of fish passage in the mainstem Yukon River complement information obtained from the sources mentioned above. The sonar is deployed at river km 197, above the unstable banks and multiple channels of the Yukon Delta, yet close enough to the mouth to provide timely and accurate escapement information. Salmon migrate from the mouth to the sonar site in approximately three days; and there is only one major spawning tributary (the Andreafsky River) below the sonar site.

The Yukon River sonar project has provided fishery managers with estimates of daily fish passage since 1986. The 1991 season focused on chinook salmon (*Oncorhynchus tshawytscha*), chum salmon (*O. keta*), and coho salmon (*O. kisutch*). Project objectives were (1) to provide daily and seasonal passage estimates for the three target species, and (2) to calculate the precision of such estimates.

METHODS

Hydroacoustic Sampling

Sample Design

Two sites were used for hydroacoustic sampling, one on either bank of the river. The right (north) bank has a stable, rocky bottom with a steep, constant slope from shore. Two transducers, both deployed within 5 m of shore and sampling to a range of 95 m, were used on the right bank. One was aimed low along the river bottom and a second was aimed higher and covered much of the remaining water column. The left (south) bank is comprised of silt and sand, and contours can be quite dynamic, depending on hydrologic conditions. One near-shore and one off-shore transducer were deployed on the left bank due to a more complex bottom slope and a tendency for fish to migrate further from shore. The first transducer was deployed within 5 m of shore and the second near a break in the bottom slope; total range was 95 m to 161 m. Changeable bottom topography required that we occasionally relocate transducers to obtain an improved aim. Both left-bank beams were aimed along the bottom.

Hydroacoustic samples were collected during three sample periods beginning at 0600, 1400, and 2130 daily. Samples were 2.5 to 2.7 hours long and consisted of four 20-minute subsamples (5 June - 3 July) or five 15-minute subsamples (4 July - 1 September). Subsamples were collected alternately from each of the two strata per bank (e.g., for the right bank before 4 July: 0600-0620 lower stratum, 0640-0700 upper stratum, 0720-0740 lower stratum, 0800-0820 upper stratum, etc).

Equipment and Procedures

Side-looking Sonar. Echosounding and transducer remote aiming equipment, as well as procedures used in their operation, were identical to those used in 1989 (LaFlamme and Mesiar 1990), with one exception. A Biosonics 111 chart recorder, rather than an EPC 3200 chart recorder, was used on the right bank after 25 June.

Downward-looking Sonar. We used a Lowrance X15 recording fathometer to monitor the river channel for presence of fish outside the range of shore-based sonar. Four to twelve bank-to-bank transects with the fathometer were completed daily from 5 June to 1 September. Transects began and ended within 100 meters upstream or downstream from the sonar transducers, on either bank of the river.

Few targets, onshore or offshore, were observed with the Lowrance for the first month, at least partially because of a low gain setting and a malfunctioning Lowrance transducer. On 30 June, during an unusually large pulse of chum salmon, we switched to a higher gain setting and began seeing numerous targets with the Lowrance, many of which were beyond sonar range. During early July, these data were used to generate in-season estimates of offshore passage. On 21 July, experiments with a spherical steel target revealed that the gain had been set unnecessarily high since 30 June. As a result the Lowrance was detecting targets substantially smaller than those detected by the shore-based sonar, resulting in overestimates of offshore fish passage. The gain setting was thereafter reduced and offshore passage estimates prior to 21 July are not reported here.

Analytical Methods

Direction of Travel. Detected targets appear as dark traces on the paper output of the EPC and Biosonics chart recorders. Since most targets travel roughly parallel to the bank, and transducer beams were aimed slightly downstream, targets changed in range (distance from the sonar transducer) over time, i.e., the traces were slanted on the chart paper. Assuming that travel was approximately parallel to the bank, angle of the trace was diagnostic of direction of travel: targets changing from long range to short range were classified as upstream-bound and targets changing from short to long range as downstream-bound. Targets which did not change in range were classified as having an unknown direction of travel. Targets of each classification were counted for each of five range intervals (sectors) in a stratum (beam). Downstream oriented targets were assumed to be debris and were not included in daily fish passage estimates. A fraction of targets with unknown orientation were added to the upstream targets, based on the relative proportion of upstream and downstream targets in that sector during that 20-minute sample, i.e.,

$$n_{(i,j)} = u_{(i,j)} + \frac{u_{(i,j)}}{u_{(i,j)} + d_{(i,j)}} z_{(i,j)} \tag{1}$$

where: n= net number of upstream oriented targets
u= upstream oriented targets
d= downstream oriented targets (assumed debris)
z= targets with unknown orientation
i= stratum
j= sector

Spatial Expansion. The shore-based sonar system does not ensonify the entire water column on either bank, and from 1986 to 1989, sonar passage estimates for the right bank upper stratum were expanded to account for the un-ensonified zone. Expansion factors were calculated by sector, based on the ratio of total water column cross-sectional area to theoretical beam cross-sectional area (Laflamme and Mesiar 1990). We did not utilize such expansions for 1991 data because the following two required assumptions do not hold: (1) that the sonar beams are conical and their exact dimensions are known, and (2) that fish distribution is uniform, or at least equally dense inside and outside of the beam. Recent studies of sonar signal attenuation at 420 kHz (Skvorc in prep.) have indicated that beam shape is not conical. Furthermore, the second assumption has not been tested and now seems implausible.

Temporal Expansion. Target counts for each range sector were converted to sector passage rates (fish per hour) by dividing by count duration (e.g., 20 minutes = 1/3 hour). These sector passage rates were then summed by transducer and the resulting transducer passage rates (one for each of 4 samples) were averaged for each 2.5 hour sonar period (Appendix A). The period passage rates for transducers 1 and 2 were summed for the right bank and rates for transducers 3 and 4 summed for the left bank. Finally, these bank passage rates were averaged over the three sonar periods per day and multiplied by 24 hours/day to yield estimates of daily fish passage by bank.

Missing Data. Equipment malfunction, severe wave action, or the need to re-deploy transducers occasionally resulted in missing sonar data. When individual subsamples within a sonar period were missed (<10% of all periods), fish passage was simply estimated based on existing subsamples for that period. When one to three complete periods were missed on a stratum (once for each stratum, on 4 July), we substituted interpolated values, i.e., the average of passage estimates for the periods preceding and following the missing period(s). The left-bank offshore transducer was not operational from 19 to 22 June when the tripod and cable became embedded in bottom sediments. During this period we extended the range of the onshore transducer from 47 m to 95 m but did not attempt to correct for data lost at longer ranges (95-142 m).

Offshore Fish Passage. Transect chart recordings were digitized to record the relative locations of targets, left and right banks, and deepest point of the river channel. From this information, depth and distance from shore were calculated for each target. The diameter of the fathometer beam was assumed to increase linearly with range (depth), causing deep targets to have a higher probability of detection than shallow targets. Therefore, to correct for unequal detection probability, we weighted individual targets by the inverse of their depth.

Targets were classified into two categories: those which were within the range of the shore-based sonar and those which were not. Daily numbers of targets (weighted by 1/depth) were summed by category and by bank. We arbitrarily chose the middle of the river as the boundary between left and right banks in 1991. The width of the (frozen) river at the sonar site (970 m) was measured directly on 5 December 1991. The ratio of (1) targets beyond sonar range to (2) targets within sonar range was multiplied by the corresponding daily estimate of onshore fish passage to obtain an estimate of offshore passage (Appendix B).

Equipment and Procedures

Gill nets were drifted through or near the sonar range on each bank to estimate species composition of upstream-bound fish. Because of the size selectivity of gill nets, seven different mesh sizes were utilized over the course of the season: 8.5" (216 mm), 7.5" (191 mm), 6.5" (165 mm), 5.5" (140 mm), 5" (127 mm), 4" (102 mm) and 2.75" (70 mm). All nets were 25 fathoms (45.7 m) long and 7.6 meters deep; and were constructed of Momoi MTC-50 or MT-50 multifilament nylon twine.

Gill-netting took place during two sample periods daily, usually at 0900-1200 and 1700-2000 hours. During each sample period, four or five nets were drifted once or twice per bank for a total of 12 to 24 drifts per day. All drifts with one net were completed before switching to the next net; drifts were done on alternate banks so there were a minimum of 20 minutes between drifts on a given bank. We altered the test-fishing schedule (which nets used and in what order) frequently during the season in response to changing riverine species composition, equipment and manpower limitations, and commercial fishing schedules (Table 1).

Four times were recorded for each drift: net start out (net starting out of boat, SO), net full out (FO), net start in (SI), and net full in (FI). Drift time was calculated as (FO-SO)/2 + (SI-FO) + (FI-SI)/2. Drifts were targeted to be 8-10 minutes in duration but were shortened when necessary to avoid snags or to limit catches during times of very high fish passage. Captured fish were identified to species and measured for length (salmon species mid-eye to tail fork, non-salmon species snout to tail fork).

Several modifications were made to test-netting procedures in 1991. To test for the presence of salmon offshore we made 30+ mid-river drifts with gill nets of all seven mesh-sizes between 21 June and 22 July 1991. The 7.6 meter deep gill nets were deployed in deep water (to 26 meters), so bottom-oriented fish were not susceptible to capture by these drifts. Total catch was one chum salmon, during a drift that strayed closer to the left-bank shore than usual.

The 2.75" mesh net (not used in 1986-1990) was first acquired in July 1991, in order to test for the presence of fish smaller than those captured in the 4" net and yet large enough to be detected by the sonar. Drifts with the 2.75" net, beginning 17 July, captured substantial numbers of least and Bering cisco (*Coregonus sardinella* and *C. laurettae*) (Appendix D). Later, as gillnet catches of larger fish continued to drop, but sonar counts did not, it became apparent that these cisco were being detected by the sonar. The 2.75" net was therefore incorporated into the test-fishing schedule and the data used to apportion sonar counts.

On 21 and 22 July, transect data began to show consistent targets near bottom in 18 to 30 feet of water 150+ meters off the left bank. These targets were beyond the range of the left-bank sonar but were partially within reach of our 7.6 meter deep nets. On 23 and 24 July we drifted the 5.5" net three times in this zone and on each occasion caught three chum salmon. Having verified that chum salmon were migrating offshore beyond sonar range, on 26 July we began drifting several mesh sizes in this zone during every test-fish period (Table 1).

By early August, the left bank sonar indicated that most targets were close to shore. Also, left bank species composition had clearly changed. Regular left bank drifts caught few chum salmon, and experimental drifts with a small-mesh herring net caught several least cisco 100 mm to 300 mm in length. On 11 August, to better monitor left bank nearshore passage of chum and coho salmon, we began to deploy a 5.5" set net at 0 to 40 m range. The set net was deployed on 10 different occasions for 1-2 hours each until 29 August.

Analytical Methods

Species proportions were derived from testfishing data based on relative catch-per-unit-effort (CPUE), under the premise that catches of each species are proportional to their relative abundance. However gill nets are size-selective, i.e., they capture efficiently only those fish within relatively narrow size ranges. Moreover, capture efficiency is variable within those ranges. Therefore we required estimates of net selectivity, to account for unequal capture probability, before we could estimate species proportions from gillnet data.

Gill-Net Selectivity. Net selectivity curves were estimated from five years (1986-1990) of Yukon River sonar test-fishing data, including more than 30,000 fish captured (gilled, wedged, or tangled) in six mesh sizes and classified into 20 mm length classes. Two methods were utilized: that of McCombie and Fry (1960) for chinook and chum salmon, and that of Holt (Peterson 1966) for coho salmon, pink salmon *(Oncorhynchus gorbuscha)*, and whitefish *(Coregonus nasus* and *C. pidchian)*. Both are based on comparison of numbers of fish caught in different mesh sizes, within length classes. The McCombie and Fry method utilizes data from many mesh sizes and makes no assumptions about curve shape. The Holt method, which assumes that selectivity curves are normal with equal variance, was used when there were inadequate numbers of mesh sizes to utilize the McCombie and Fry method. Holt selectivity curves were truncated for length classes in which the data did not appear to conform to the assumption of normality. Resulting curves are shown in Figure 1.

Species Proportions. Relative CPUE, adjusted for net selectivity, was used to calculate daily species proportions. Adjusted CPUE (defined below) was calculated by 20 mm length class, then length class CPUE's were summed for each species. Summed CPUE for a given species, divided by the total CPUE for all species, was used as the estimated proportion of that species for the day.

Adjusted CPUE for a given length class was calculated as adjusted catch, divided by effort (fathom-hours) expended in catching that length class (Figure 2). Heights and ranges of selectivity curves governed how both catch and effort were calculated. Catches of fish in a given length class were first adjusted for unequal probability of capture by dividing by the height of the selectivity curve (specific to species and net) for that length value. Effort expended in catching fish of a given length class was calculated by summing fathom-hours for all nets which captured those fish with known probability, i.e., nets for which the selectivity curve had been estimated for that length value.

From one to four mesh sizes were used to estimate the abundance of each species (Table 2). Data from fish with unknown probability of capture (size outside the range of estimated selectivity curves) were discarded as anomalous; however few fish (8%) fell into this category. We lacked selectivity estimates for sheefish *(Stenodus leucichthys)*, cisco, and other minor species (totalling 11% of all fish caught). If we opted to make no selectivity adjustments for these species, their relative abundance would be underestimated since catches of other species were multiplied by adjustment factors greater than one. So instead, we calculated the mean adjustment factor for species with selectivity curves, and multiplied it (1.44) by all catches of species without curves, regardless of length.

Missing Data. When a partial or full test fishing sample period was missed, species proportions were calculated using the test fishing data available for that day. No test-fishing was done on 4 July; test-fishing data from 5 July were used to apportion 4 July sonar counts. Insufficient fish were caught on the left bank on 18 August to estimate species proportions, so data from 17-18 August were pooled to generate species proportions.

Daily Fish Passage. Daily estimates of fish passage, by species and by bank, were obtained by multiplying total fish passage by estimated species proportions. Left and right bank species passage estimates were then added to obtain daily (within-sonar-range) species passage estimates.

From 21 July to 1 September, we also estimated passage of fish beyond the range of the shore-based sonar systems. Total offshore passage, estimated from bank-to-bank transect data, was apportioned using the left-bank offshore test-net results. When daily transect or offshore test-net data were insufficient to estimate offshore-to-onshore ratios or sets of species proportions, respectively, data were pooled for two or more consecutive days to generate the required estimates (21-25 July, 26-28 July, 30-31 July, 4-6 August, 7-8 August, 14-16 August, 17-20 August, 21-22 August, 23-24 August, 27-29 August, and 31 August-1 September).

Left bank nearshore set nets caught no upstream-bound chum or coho salmon from 11 to 29 August; nearshore sonar targets during this time were probably comprised mostly of cisco and whitefish. Inspection of left bank sonar and test-fishing data indicated that this phenomenon likely began about 1 August. Therefore from 1 August to 1 September, sonar counts in stratum 3, sectors 1 and 2 (0 to 38 meters from the left shore) were excluded when calculating left bank passage. Set-net data, collected within 40 m of shore to monitor nearshore chum salmon and coho salmon passage, were not used to apportion the offshore (38-161 m) left bank sonar counts.

Variance Estimation

As detailed above, estimates of daily passage by species were generated by multiplying estimates of (1) fish passage through the sonar beams by (2) species proportions derived from test gill-netting. From 21 July to 1 September, we also estimated (3) the ratio of offshore to onshore fish, using bank-to-bank transect data. All three of the above estimates are subject to sampling error. To estimate the variance of daily species passage estimates (functions of the above three components), we first estimated the variance of each individual component.

Fish Passage Through Sonar Beams

Sonar sampling periods, each 2.5 hours long, were obtained at regular (systematic) intervals of 8 hours. Treating the systematically sampled sonar counts as a simple random sample would overestimate the variance of the total, since sonar counts were highly autocorrelated (Wolter 1985). Brannian (1986) recommended the following variance estimator (Equation 2, modified from Wolter 1985), based on squared differences of successive observations and roughly equivalent to stratifying the season into 16 hour blocks.

$$\textbf{\textit{Total fish passage}}\ (\hat{Y}_i):\quad v\hat{a}r(\hat{Y}_i) = e_t^2\,\frac{1-f}{n_i}\sum_{j=2}^{n_i}\frac{(\hat{y}_{ij}-\hat{y}_{i,j-1})^2}{2(n_i-1)} \qquad (2)$$

where: $\hat{Y}_i$ = estimated number of fish (all species) passing sonar site during day i

$\hat{y}_{ij}$ = estimated number of fish passing sonar site during 2.5 hour sampling period j of day i

f = primary stage sampling fraction = 2.5 hrs / 8 hrs = 0.31

n_1 = number of sampling periods per day (usually 3)

e_t = temporal expansion factor = 24 hrs / 2.5 hrs = 9.6

Species Proportions

Total fish passage was allocated to species by drifting a suite of gill nets twice daily (morning and evening) on each bank. Species proportions were estimated from relative daily CPUE (pooled for morning and evening drifts), after adjusting for the effects of gill net selectivity (Figure 3). In order to estimate variances of these proportions, we generated two replicate sets of species proportion estimates, one each for the morning and evening sets of drifts. Variance of the proportions were calculated after Cochran (1977:64), weighting each replicate by total (all species) CPUE (Equation 5).

$$\textit{Spp proportions } (\hat{p}_i): \quad v\hat{a}r(\hat{p}_i) = \frac{1}{n_2}\sum_{k=1}^{n_2}\left(\frac{m_{ik}}{\overline{m}_i}\right)^2 \frac{(\hat{p}_{ik}-\hat{p}_i)^2}{n_2-1} \quad (3)$$

where: $\hat{p}_i$ = estimated proportion of one species (e.g. chinook salmon) out of total fish passage during day i

n_2 = number of test-fish samples per day (usually 2)

m_{ik} = test-fishing CPUE during sample period k of day i

$\overline{m}_i$ = mean test-fishing CPUE during day i

$\hat{p}_{ik}$ = estimated proportion of one species out of total fish passage during the sample period k of day i

Offshore to Onshore Ratios

Calculating the variance of offshore to onshore ratios parallels exactly that of species proportions. Two sets of transects were done daily and separate ratios were generated from each. Squared deviations from the pooled daily ratio were weighted by the number of targets within the beams for each transect set.

$$\textbf{\textit{Offshore/onshore ratio}}\ (\hat{r}_i):\ \hat{var}(\hat{r}_i) = \frac{1}{n_3}\sum_{l=1}^{n_3}\left(\frac{t_{il}}{\bar{t}_i}\right)^2 \frac{(\hat{r}_{il}-\hat{r}_i)^2}{n_3-1} \quad (4)$$

where: $\hat{r}_i$ = estimated ratio of offshore to onshore targets on day i

n_3 = number of transect sets per day (usually 2)

t_{il} = number of targets within sonar range during transect set l of day i

$\bar{t}_i$ = mean number of targets within sonar range on day i

$\hat{r}_{il}$ = estimated offshore:onshore ratio during transect set l of day i

Species Passage Estimates

Sonar-derived estimates of total fish passage were largely independent of gillnet-derived estimates of species proportions. Therefore we calculated the variance of their product (daily onshore species passage estimates) after Goodman's (1960) formula for variance of the product of two independent random variables (Equation 5).

$$\textbf{\textit{Species passage}}\ (\hat{z}_i = \hat{Y}_i * \hat{p}_i)$$

$$\hat{var}(\hat{z}_i) = \hat{Y}_i^2\hat{var}(\hat{p}_i) + \hat{p}_i^2\hat{var}(\hat{Y}_i) - \hat{var}(\hat{Y}_i)\hat{var}(\hat{p}_i) \quad (5)$$

where: $\hat{z}_i$ = estimated passage of one species during day i.

Offshore species passage estimates (21 July - 1 September) required that three independent components be multiplied: onshore sonar counts, offshore to onshore ratio, and species proportions. Variance of these estimates was calculated by applying Goodman's (1960) method twice. The variance of the offshore passage estimate (all species, i.e., $W_i=Y_ix_i$) was calculated first, by substituting offshore to onshore ratio r_i for species proportion p_i in Equation 5. The variance of daily offshore passage by species, (i.e., W_ip_i) was then obtained by substituting W_i for Y_i in Equation 5.

Finally, daily variance estimates for the two banks were added and then summed over the season. Coefficients of variation were calculated in the customary way (square root of the variance divided by the point estimate).

We developed SAS program code (Appendix F) to calculate passage estimates and their variances. Rbase for DOS was used for data entry, storage, and retrieval.

RESULTS

We operated the sonar project from 5 June through 1 September in 1991. Excluding the first two sectors of the left bank nearshore stratum after 31 July, an estimated 1,875,334 ± 38,200 (s.e.) fish passed upstream through the sonar beams during this period, 1,302,057 ± 35,642 (69%) along the left bank and 573,276 ± 13,744 (31%) along the right bank. Bank-to-bank transect data suggested that an additional 452,448 ± 70,519 fish passed beyond the range of the sonar from 21 July through 1 September (Appendix C). Distribution of fish among the two banks and the offshore zone varied considerably over the season (Figure 3).

We captured 6,452 fish during 1,690 drifts with gill nets (total 13,702 minutes fished) during the season. We caught 3,366 fish in 709 drifts on the right bank, 2,891 fish in 785 drifts on the left bank, and 189 fish in 194 drifts offshore (beyond sonar range) on the left bank. The catch included 4,423 chum salmon, 586 chinook salmon, 501 coho salmon, 25 pink salmon, 88 sheefish, 192 whitefish, and 565 cisco (Appendix D).

Total upstream fish passage within the sonar beams was comprised of an estimated 75,681 chinook salmon, 1,473,614 chum salmon, 59,822 ± 4,797 (s.e.) coho salmon, and 266,217 other fish. Chinook salmon were comprised of 58,079 ± 7,023 fish greater than 700 mm in length, and 17,602 ± 3,195 "jacks" shorter than 700 mm. Most (1,232,874 ± 36,130) of the chum salmon passed during the early "summer" season (through 18 July); the remainder (240,740 ± 14,646) passed during the late "fall" season (19 July through 1 September). An additional 356,182 ± 62,742 chum salmon and 10,903 ± 5,747 coho salmon passed beyond the range of the sonar after 20 July, as estimated from bank-to-bank transect data and offshore drifts (Table 3). Chinook salmon passage peaked on 26 June (4,734), chum salmon on 1 July (146,593), and coho salmon on 24 August (6,344)(Figure 4).

DISCUSSION

Numerous improvements have been made to the Yukon Sonar Project in recent years. Data processing procedures have been streamlined, net selectivity estimates have been improved, variance estimates have been developed, sonar and testfishing procedures have been further refined, and methodology has been developed to detect and begin to estimate passage of fish offshore. We have steadily acquired greater knowledge, enabling more rigorous passage estimates with each year of the project's operation.

Sonar Signal Attenuation

Recent experimental work (Skvorc, Alaska Department of Fish and Game, Anchorage, personal communication) has indicated that the intensity of the 420 kHz sonar signal (utilized on the Yukon) attenuates with range. This finding has several implications. First, the longitudinal cross section of the sonar beam is not triangular, i.e., its diameter does not increase linearly with range. Rather, the beam increases in diameter to a certain range, then decreases in diameter and fades out altogether. Consequently, the Yukon sonar transducers are actually ensonifying substantially less cross-sectional area of the river than originally assumed. Second, attenuation eliminates our ability to use voltage thresholds to exclude small fish from detection. When the sonar signal attenuates with range, the effect of a voltage threshold also varies with range. If we set a threshold to exclude fish smaller than, say, 450 mm at 20 m range, fish larger than 450 mm would be excluded at ranges greater than 20 m. As a result we are forced to use very low thresholds, which in turn means we count small fish and require nets of many mesh sizes to determine species composition.

Preparations are presently being made to convert the project's echo sounders to 120 kHz capabilities, and to obtain 120 kHz transducers. Attenuation of 120 kHz signals is insignificant. The new equipment is expected to be ready for the 1992 late season, beginning in mid-July.

Offshore Distribution of Fish

Substantial passage of fish offshore, beyond the range of the shore-based sonar, was discovered in August 1990. Transects with a Lowrance X15 fathometer had been initiated in June 1990 to test for the possible migration of chinook salmon in mid-river, but few offshore targets were seen until August, by which time a large sand bar had formed hundreds of meters offshore. Many targets were detected (using the Lowrance) along this sandbar during the remainder of the 1990 fall chum run.

We continued the transects with the Lowrance in 1991, not expecting to see fish offshore unless the sand bar formed again. We had several problems with the Lowrance, including a malfunctioning transducer and difficulty determining the correct gain setting. When these problems were resolved on 21 July, we began detecting targets offshore beyond the sonar range on the left bank. Drift netting yielded few fish, but indicated that some of the detected targets were chum salmon. With our present techniques (which may overestimate offshore passage) we estimated that almost 50 percent more fall chum salmon (356,000) migrated out in this zone than migrated through the sonar beams (241,000), even though the sand bar did not form in 1991. It is possible that the side-looking sonar has missed substantial numbers of late-season offshore fish in years previous to 1990, with or without the presence of a sand bar in mid-river.

We first detected fish offshore on 21 July in 1991, however we cannot be certain exactly when offshore passage began. Lowrance data were too inconsistent before 21 July (see above) to provide reliable information. Mid-river drifts between 21 June and 22 July caught only one chum salmon; however these drifts were done in deep water where our nets could not reach bottom-oriented fish. On 23 July, when we began drifting just offshore of the sonar range (150+ meters from shore, in water slightly shallower than our nets), we immediately began to catch chum salmon from near the bottom.

Fish passing outside the sonar range potentially pose a significant sampling problem. Existing equipment is ill-equipped to deal with this issue. Lowrance fathometers are considerably less sophisticated than Biosonics echo sounders; the user has little control over transmit and receive parameters, and characteristics of the sonar beam are less well known, making it difficult to accurately exclude detection of small fish. Offshore passage estimates proved very sensitive to receiver gain settings on the Lowrance and to estimates of river width. Fish in shallow water near shore may be difficult to detect as a result of (1) boat avoidance and (2) excessive electronic noise in the signal within 2-3 meters of the surface. Finally, in deep water it is difficult to net fish; at present we have no direct way to estimate species composition of fish beyond reach of our gill nets (7.6 m deep). Lowrance data showed targets to depths of 13 meters and greater.

It may be possible to increase the proportion of the river which we ensonify from shore, which would significantly improve the accuracy and precision with which we estimate fall chum passage rates. The river narrows appreciably (from 970 m to 525-625 m, depending on water level) several hundred meters downstream from the present sonar site. Bank to bank transects done at this location during 9-23 August 1991 showed relatively more fish travelling closer to shore than at the sonar site, especially on the left bank. Relocating the left bank sonar a short distance downriver might enable detection of more fish from shore and thereby reduce or eliminate our dependence on transect data. Unfortunately the left bank bottom profile has historically been unstable, changing within and between seasons. Finding a profile acceptable for sonar at this location may be difficult. Should we find an acceptable profile, use of 120 kHz frequency will also help to extend the sonar range.

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Table 1a.: Gill nets drifted for species apportionment, Yukon River Sonar 1991 early season (L = left bank, R = right bank, M = middle [offshore left bank]).

DATE	TESTFISH PERIOD 1						TESTFISH PERIOD 2				
05JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
06JUN	8.50 LR	6.50 LR	5.00 LR	8.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
07JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
08JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
09JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
10JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
11JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
12JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
13JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
14JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
15JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
16JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
17JUN	8.50 LR	5.50 LR	4.00 LR	7.50 LR			7.50 LRLR	6.50 LR	5.00 LR	8.50 LRLR	
18JUN	8.50 LR	6.50 LR	5.00 LR	7.50 LR			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
19JUN	8.50 LRL	6.50 LR	5.00 LR	7.50 LR	5.50 LR	4.00 LR					
20JUN	8.50 LRLR	6.50 LR	5.00 LR	7.50 LR			7.50 LRLR	5.50 LR	4.00 LR	8.50 LRLR	
21JUN	8.50 LRL	5.50 LR	4.00 LR	7.50 LRLR			7.50 LRL	6.50 LR	5.00 LR		
22JUN	8.50 LRLR	6.50 LR	5.00 LR	7.50 LRL			7.50 LRLR	5.50 LR	4.00 LR	8.50 LRLR	
23JUN	8.50 LRLR	5.50 LR	4.00 LR	7.50 LRLR	5.00 LR	6.50 LR					
24JUN	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
25JUN	8.50 LRL	5.50 LR	4.00 LR	7.50 LR			7.50 LR	6.50 LR	5.00 LR	8.50 LRL	
26JUN	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL	5.50 LR	4.00 LR					
27JUN	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
28JUN	8.50 LRL	6.50 LR	5.00 LR	7.50 LR			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
29JUN	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
30JUN	8.50 LRLR	6.50 LR	5.00 LR	7.50 LRL	4.00 LR	5.50 LR					
01JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LR	6.50 LR	5.00 LR	8.50 LR	
02JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
03JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL	5.00 LR	6.50 LR					
04JUL											
05JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
06JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
07JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
08JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 RL			7.50 LR	5.50 LR	4.00 LR	8.50 LR	
09JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LR			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
10JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
11JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
12JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
13JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
14JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
15JUL	8.50 LRL	5.50 LR	4.00 LR	7.50 LRL			7.50 LRL	6.50 LR	5.00 LR	8.50 LRL	
16JUL	8.50 LRL	6.50 LR	5.00 LR	7.50 LRL			7.50 LRL	5.50 LR	4.00 LR	8.50 LRL	
17JUL	8.50 LR	2.75 LR	5.50 LR	4.00 LR	7.50 LR		7.50 LR	2.75 LR	6.50 LR	5.00 LR	8.50 LR
18JUL	8.50 LR	2.75 LR	6.50 LR	5.00 LR	7.50 LR		7.50 LR	2.75 LR	5.50 LR	4.00 LR	8.50 LR

Table 1b.: Gill nets drifted for species apportionment, Yukon River Sonar 1991 late season (L = left bank, R = right bank, M = middle [offshore left bank]).

DATE	TESTFISH PERIOD 1					TESTFISH PERIOD 2				
19JUL	6.50 LR	5.50 LR	5.00 LR	4.00 LR	2.75 LR	2.75 LRL	4.00 LR	5.00 LR	5.50 LR	6.50 LR
20JUL	6.50 LR	5.50 LR	5.00 LR	4.00 LR	2.75 LR	2.75 LR	4.00 LR	5.00 LR	5.50 LR	6.50 LR
21JUL	6.50 LR	5.50 LR	5.00 LR	4.00 LR	2.75 LR	2.75 LLR	4.00 LR	5.00 LR	5.50 LR	6.50 LR
22JUL	6.50 LR	5.50 LR	5.00 LR	4.00 LR	2.75 LR	2.75 LR	4.00 LR	5.00 LR	5.50 LR	6.50 LR
23JUL	6.50 LR	5.50 LR	5.00 LR	4.00 LR	2.75 LR	2.75 LR	4.00 LR	5.00 LR	5.50 LMR	6.50 LR
24JUL	6.50 LR	5.50 LMR	5.00 LR	4.00 LR	2.75 LR	2.75 LR	4.00 LR	5.00 LR	5.50 LMR	6.50 LR
25JUL	6.50 LR	5.50 LMR	5.00 LR	4.00 LR	2.75 LR	2.75 LR	4.00 LR	5.00 LR	5.50 LMR	6.50 LR
26JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
27JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 L	5.00 LR	6.50 LMR	
28JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
29JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
30JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
31JUL	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LR	
01AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	6.50 LMR	4.00 LMR	5.00 LR	
02AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
03AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
04AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	6.50 LMR			
05AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
06AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	5.00 LR	6.50 LMR	5.00 L	
07AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	5.00 LR	6.50 LMR	5.00 L	
08AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LR	4.00 LMR	5.00 LR	6.50 LMR	
09AUG	6.50 LR	5.50 LMR	4.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.00 LMR	6.50 LMR	
10AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 R	5.00 LMR	6.50 LMR	
11AUG	6.50 LMR	5.00 LMR	2.75 LMR			2.75 LMR	4.00 LR	5.00 LMR	6.50 LMR	
12AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
13AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
14AUG	6.50 LMR	5.00 LMR	2.75 LMR			2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
15AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
16AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
17AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	5.00 LMR	6.50 LMR		
18AUG	6.50 LMR	5.50 LMR	5.00 LMR	4.00 LR	2.75 LMR					
19AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
20AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
21AUG	6.50 LMR	5.00 LMR	2.75 LMR			2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
22AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
23AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
24AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 R	5.00 LMR	6.50 LR		
25AUG	6.50 LMR	5.00 LMR	2.75 R			2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
26AUG	6.50 LMR	5.50 LMR	5.00 R	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
27AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
28AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
29AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
30AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
31AUG	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	
01SEP	6.50 LMR	5.50 LMR	5.00 LR	2.75 LMR		2.75 LMR	4.00 LR	5.50 LMR	6.50 LMR	

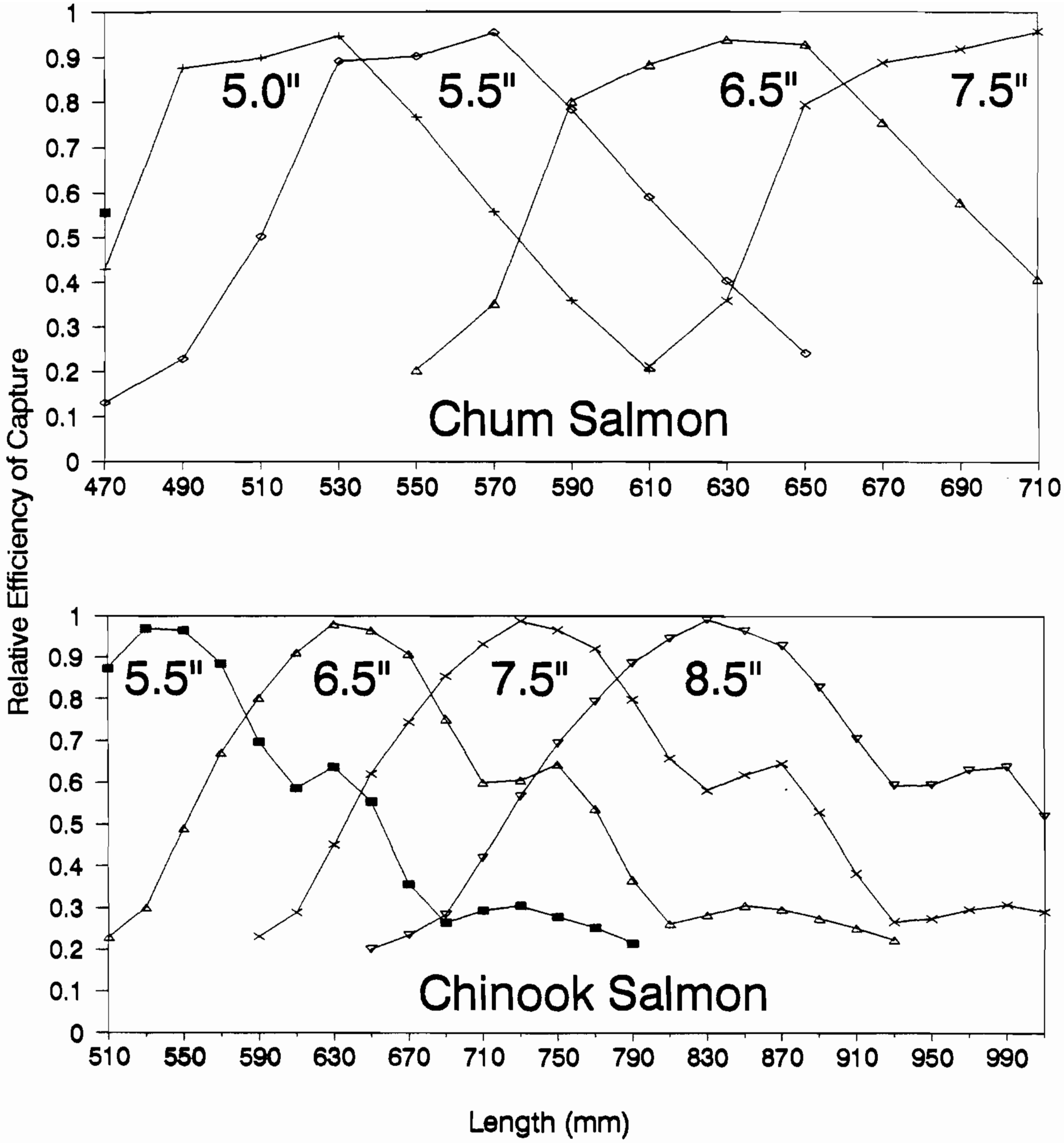

Figure 1a. Net selectivity curves used to adjust catches of chum salmon and chinook salmon for unequal probability of capture, Yukon River sonar, 1991.

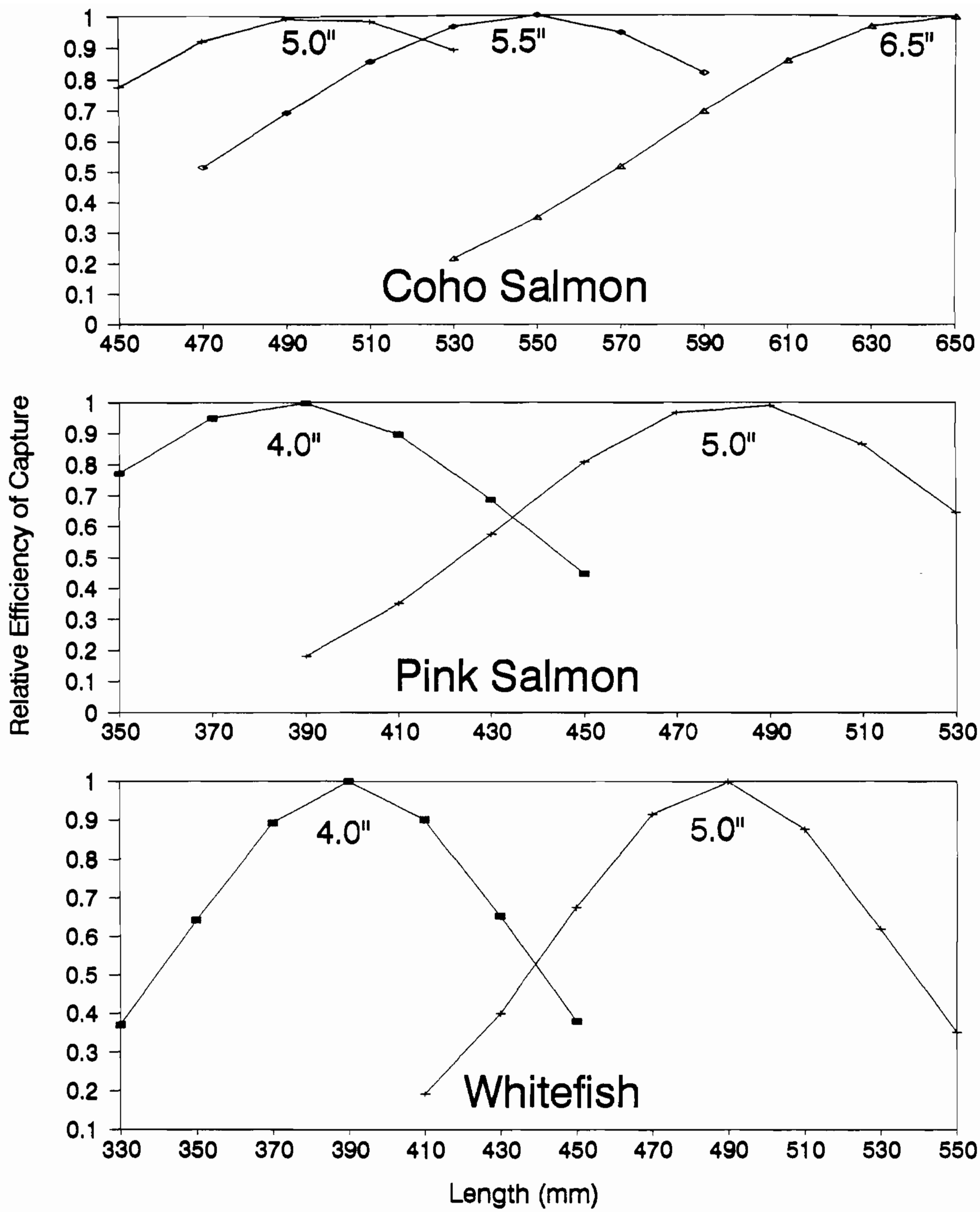

Figure 1b. Net selectivity curves used to adjust catches of coho salmon, pink salmon, and whitefish for unequal probability of capture, Yukon River sonar, 1991.

Table 2. Mesh sizes used to determine relative abundance of fish species present in the Yukon River 1991. Data from meshes with a "1" in the appropriate column were used to calculate relative CPUE for that species. Catches of species with "Y" in the last column were adjusted for net selectivity.

	2.75	4.0	5.0	5.5	6.5	7.5	8.5	ADJUST?
CHINOOK	0	0	0	1	1	1	1	Y
SCHUM[1]	0	0	1	1	1	1	0	Y
FCHUM[2]	0	0	1	1	1	1	0	Y
COHO	0	0	1	1	1	0	0	Y
PINK	0	1	1	0	0	0	0	Y
SHEEFISH	0	0	0	1	1	1	0	N
WHITE	0	1	1	0	0	0	0	Y
JACK	0	0	0	1	1	1	0	Y
OTHER	0	1	1	1	0	0	0	N
CISCO	1	1	0	0	0	0	0	N

(1) Summer-run chum salmon
(2) Fall-run chum salmon

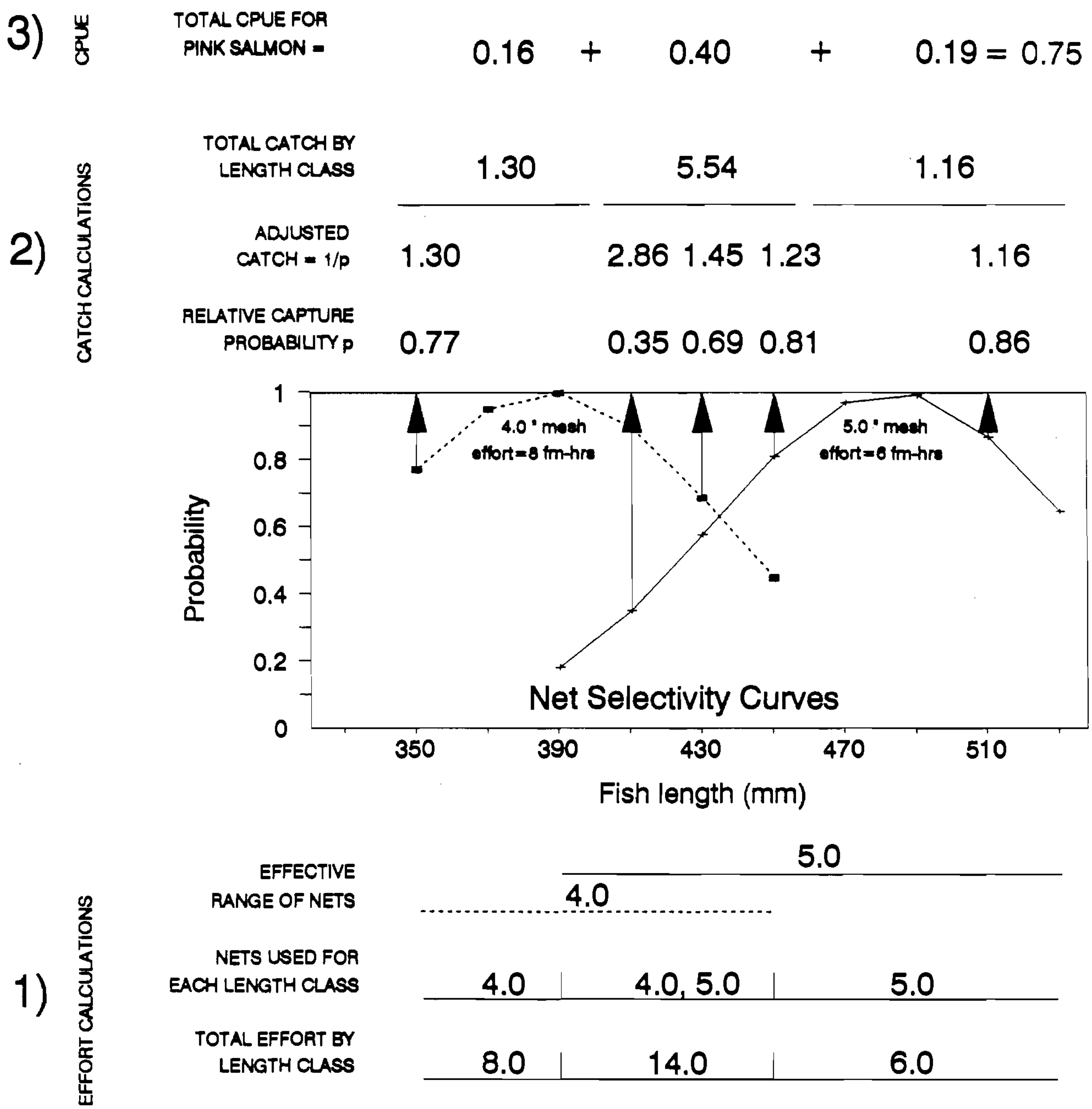

Figure 2. An example of how daily adjusted CPUE is calculated for one species (pink salmon). In this example two pink salmon (of lengths 350 mm and 430 mm) were caught in drifts with 4" mesh nets, and three pink salmon (410, 450, and 510 mm) were caught in 5" mesh nets. Total effort for 4" mesh nets was 8 fathom hours; effort for 5" mesh nets was 6 fathom hours. First, each net is assigned a range of pink salmon lengths which are susceptible to capture by that net, based on estimated net selectivity curves. Where net ranges overlap, daily effort for both nets are summed. Second, catches of each fish are adjusted upwards, based on estimated selectivity curves for each net, to account for differential capture probabilities for different length fish. Adjusted catches are summed by length class. Finally, adjusted catches for each length class are divided by the appropriate effort (from step 1), and the adjusted CPUE's summed over all length classes. This number, divided by total CPUE for all species and all length classes, is used as an estimate of the proportion of pink salmon present.

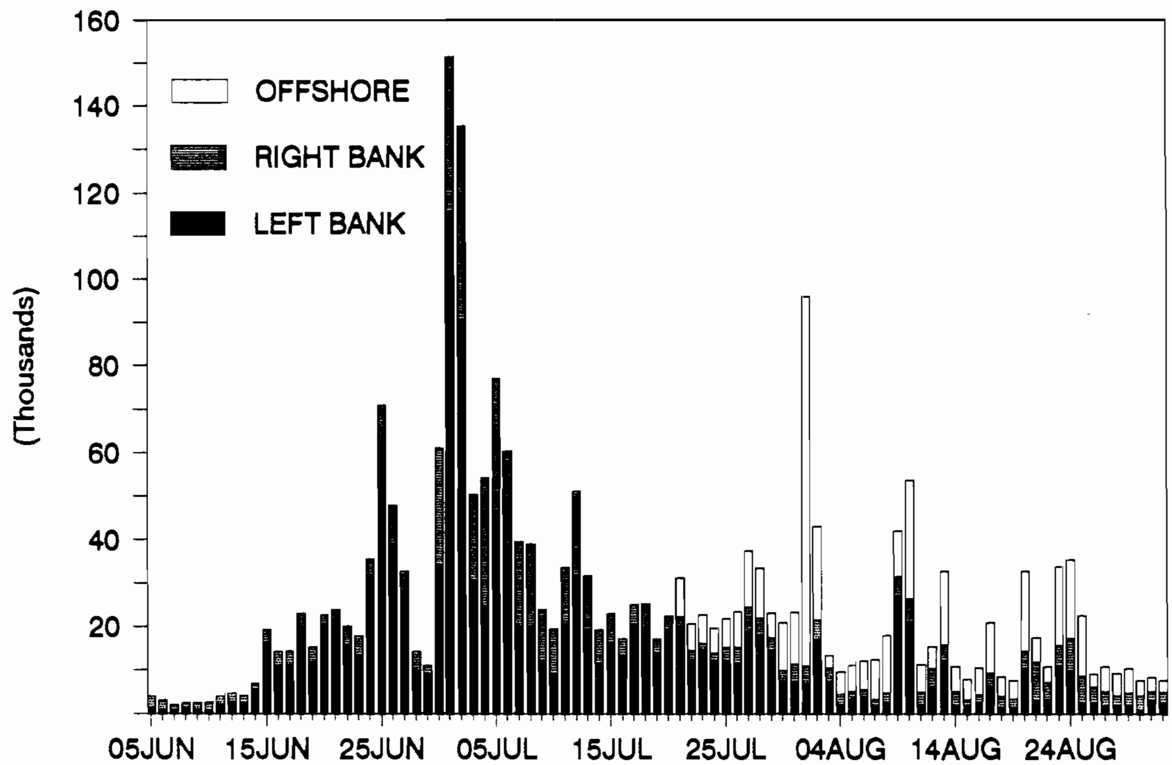

Figure 3. Estimated daily fish passage, by location, Yukon River 1991.

Table 3a. Daily estimates of Yukon River fish passage, by species, within range of the shore-based sonar, 5 June to 18 July, 1991.

DATE	CHINOOK	JACK	CHUM	OTHER
05JUN	0	0	396	3,671
06JUN	838	268	323	1,755
07JUN	485	631	289	702
08JUN	839	0	790	993
09JUN	1,050	0	114	1,457
10JUN	1,180	0	1,166	379
11JUN	1,586	574	1,252	587
12JUN	973	286	1,898	1,631
13JUN	1,717	127	2,142	312
14JUN	2,758	426	3,461	325
15JUN	3,358	2,051	13,557	231
16JUN	2,252	407	11,599	0
17JUN	703	1,203	11,875	566
18JUN	1,759	1,719	19,364	161
19JUN	1,107	519	13,244	365
20JUN	296	73	22,166	115
21JUN	3,178	117	20,577	0
22JUN	511	173	19,155	218
23JUN	1,175	0	14,679	1,840
24JUN	75	2,316	31,082	2,004
25JUN	3,288	0	67,384	264
26JUN	4,734	860	42,204	0
27JUN	2,585	1,099	23,054	5,876
28JUN	2,519	1,757	7,079	2,859
29JUN	2,959	0	8,080	66
30JUN	2,148	213	57,925	747
01JUL	3,531	376	146,593	892
02JUL	1,705	1,222	131,643	701
03JUL	1,659	750	45,536	2,438
04JUL	267	0	53,639	320
05JUL	331	0	76,460	330
06JUL	687	281	59,068	282
07JUL	951	0	38,256	352
08JUL	858	0	37,262	789
09JUL	638	0	22,963	268
10JUL	325	153	18,348	605
11JUL	624	0	32,534	455
12JUL	788	0	50,146	120
13JUL	608	0	30,981	0
14JUL	243	0	19,034	0
15JUL	403	0	21,887	697
16JUL	74	0	15,630	1,448
17JUL	0	0	21,280	3,672
18JUL	310[a]	0	16,761	8,363
	======	======	=========	======
	58,079	17,602	1,232,874	48,856
S.E.	7,023	3,195	36,130	
C.V.	0.12	0.18	0.03	

(a) Includes 130 chinook salmon on 22 July.

Table 3b. Daily estimates of Yukon River fish passage, by species, 19 July to 1 September, 1991. Offshore estimates (beginning 21 July) are for fish travelling outside of the range of the shore-based sonar.

	CHUM			COHO			OTHER[1]		
DATE	ONSHORE	OFFSHORE	TOTAL	ONSHORE	OFFSHORE	TOTAL	ONSHORE	OFFSHORE	TOTAL
19JUL	10,935		10,935	0		0	6,349		6,349
20JUL	15,654		15,654	0		0	6,732		6,732
21JUL	11,797	8,948	20,745	0	0	0	10,411	0	10,411
22JUL	6,432	6,041	12,473	0	0	0	8,019	0	8,019
23JUL	4,359	6,445	10,804	0	0	0	11,803	0	11,803
24JUL	3,742	5,685	9,427	0	0	0	10,225	0	10,225
25JUL	5,078	6,542	11,620	0	0	0	10,223	0	10,223
26JUL	5,881	4,919	10,800	0	0	0	9,411	3,240	12,651
27JUL	6,640	7,799	14,439	0	0	0	17,831	5,136	22,967
28JUL	4,585	6,878	11,463	0	0	0	17,326	4,530	21,856
29JUL	703	0	703	0	0	0	16,817	5,566	22,383
30JUL	377	6,834	7,211	2,856	0	2,856	6,611	4,126	10,737
31JUL	734	7,416	8,150	0	0	0	10,732	4,477	15,209
01AUG	8,240	72,460	80,700	137	0	137	2,510	12,645	15,155
02AUG	17,707	21,596	39,303	0	0	0	3,898	0	3,898
03AUG	5,910	2,825	8,735	0	0	0	4,542	0	4,542
04AUG	226	2,984	3,210	0	0	0	4,335	2,042	6,377
05AUG	0	3,520	3,520	0	0	0	5,120	2,409	7,529
06AUG	2,546	3,897	6,443	0	0	0	3,069	2,667	5,736
07AUG	1,237	2,347	3,584	106	0	106	2,092	6,674	8,766
08AUG	0	3,381	3,381	518	0	518	4,356	9,612	13,968
09AUG	27,270	9,345	36,615	0	0	0	4,233	1,202	5,435
10AUG	22,494	25,878	48,372	3,057	1,448	4,505	734	0	734
11AUG	1,098	6,192	7,290	585	0	585	3,304	0	3,304
12AUG	7,365	667	8,032	1,016	618	1,634	1,941	3,821	5,762
13AUG	8,246	8,591	16,837	1,161	0	1,161	6,483	8,224	14,707
14AUG	2,044	3,234	5,278	1,845	0	1,845	1,334	2,449	3,783
15AUG	1,938	2,537	4,475	1,074	0	1,074	413	1,921	2,334
16AUG	333	3,476	3,809	617	0	617	3,443	2,632	6,075
17AUG	1,905	11,623	13,528	2,340	0	2,340	5,104	0	5,104
18AUG	1,885	4,595	6,480	1,415	0	1,415	802	0	802
19AUG	1,911	4,126	6,037	1,056	0	1,056	599	0	599
20AUG	10,090	18,303	28,393	3,600	0	3,600	768	0	768
21AUG	7,115	5,578	12,693	3,796	156	3,952	841	0	841
22AUG	603	3,484	4,087	5,987	97	6,084	652	0	652
23AUG	12,528	17,979	30,507	2,900	0	2,900	244	0	244
24AUG	9,075	17,963	27,038	6,344	0	6,344	1,918	0	1,918
25AUG	3,435	12,127	15,562	4,608	1,688	6,296	663	0	663
26AUG	2,857	3,088	5,945	2,483	0	2,483	800	0	800
27AUG	0	4,337	4,337	2,273	1,448	3,721	2,844	0	2,844
28AUG	1,090	3,738	4,828	2,485	1,248	3,733	763	0	763
29AUG	1,641	4,184	5,825	1,547	1,397	2,944	1,684	0	1,684
30AUG	840	0	840	983	1,543	2,526	2,453	1,991	4,444
31AUG	663	2,452	3,115	1,902	669	2,571	2,637	0	2,637
01SEP	1,529	2,166	3,695	3,131	591	3,722	292	0	292
	=======	=======	=======	======	=====	======	=======	======	=======
	240,740	356,182	596,922	59,822	10,903	70,725	217,361	85,363	302,724
S.E.	14,646	40,298		4,797	5,747				
C.V.	0.06	0.11		0.08	0.53				

(1) Estimates for other species do not include fish passing within 38 m of shore on left bank after 31 July.

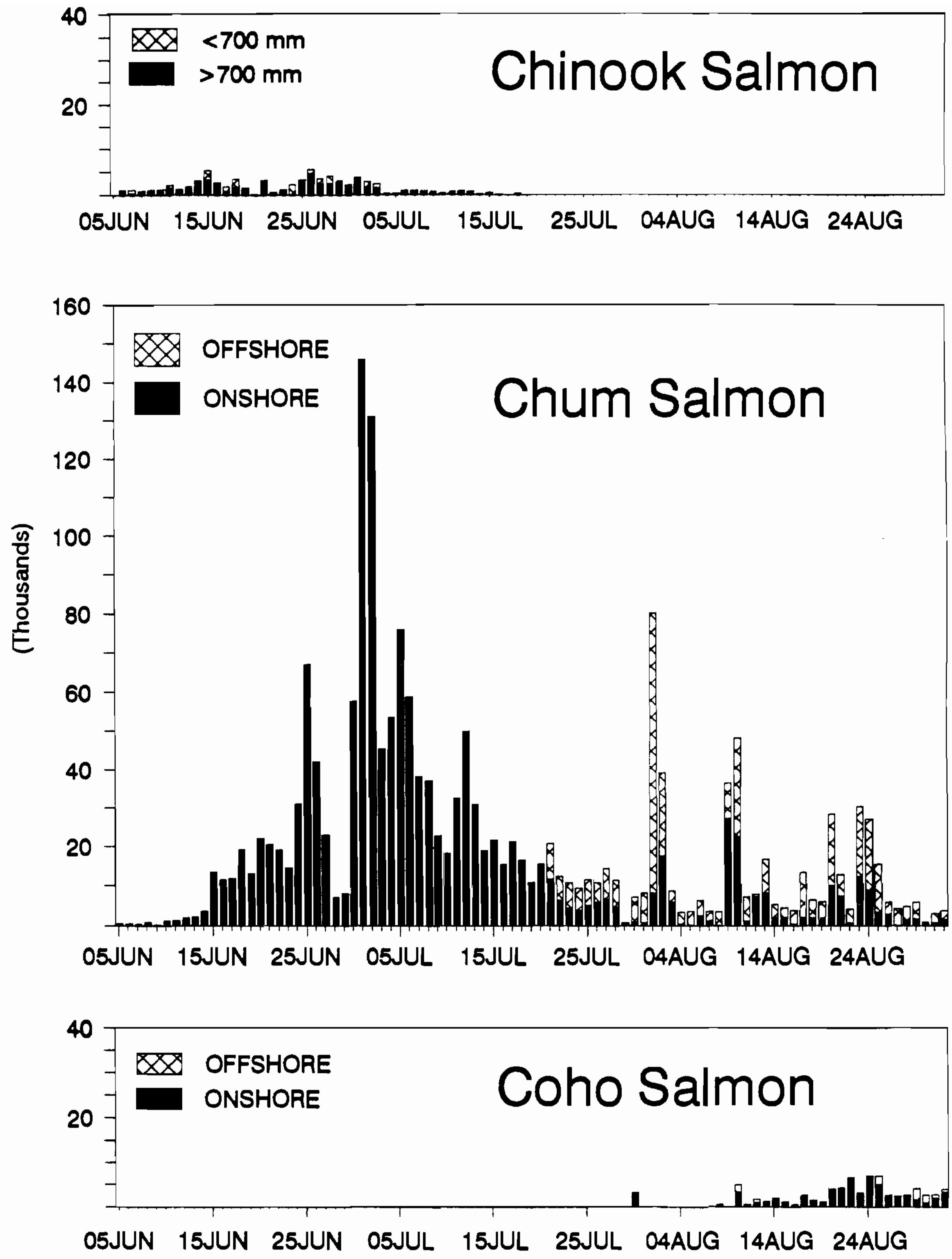

Figure 4. Estimated daily passage of chinook, chum, and coho salmon, Yukon River 1991.